MAGNETIC ACTUATORS AND SENSORS

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Preface

This book is written for practicing engineers and engineering students involved with the design or application of magnetic actuators and sensors. The reader should have completed at least one basic course in electrical engineering and/or mechanical engineering. This book is suitable for engineering college juniors, seniors, and graduate students.

IEEE societies whose members will be interested in this book include the Magnetics Society, Computer Society, Power Engineering Society, Industry Applications Society, and Control System Society. Readers of the *IEEE/ASME Transactions on Mechatronics,* sponsored by the IEEE Industrial Electronics Society, may also want to read this book. Many SAE (Society of Automotive Engineers) members might also be very interested in this book because the magnetic devices discussed here are commonly used in automobiles and aircraft.

This book is a suitable text for upper-level engineering undergraduates or graduate students in courses with titles such as "Actuators and Sensors" or "Mechatronics." It can also serve as a supplementary text for courses such as "Electromagnetic Fields," "Electromechanical Energy Conversion," or "Feedback Control Systems." It is also appropriate as a reference book for "Senior Projects" in electrical and mechanical engineering. Its basic material has been used in a 16-hour seminar for industry that I have taught many times at Milwaukee School of Engineering. More than twice as many class hours, however, will be required to thoroughly cover the contents of this book.

The chapters on magnetic actuators are intended to replace a venerable book by Herbert C. Roters, *Electromagnetic Devices,* published by John Wiley & Sons in 1941. Over the decades since 1941, many technological revolutions have occurred. Perhaps the most wide-ranging revolution has been the rise of the modern computer. The computer not only uses magnetic actuators and sensors in its disk drives and external interfaces but also enables new ways of analyzing and designing magnetic devices. Hence this book includes the latest computer-aided engineering methods from the most recently published technical papers. The latest software tools are used, especially the electromagnetic finite-element software package Maxwell SV, which is available to students at no charge from Ansoft Corporation, for which I am a part-time consultant. Other software tools used include SPICE, MATLAB, and Simplorer. Simplorer SV, the student version, is also available to students free of charge from Ansoft Corporation. If desired, the reader can work the computational

examples and problems with other available software packages, which should yield similar results. To download Maxwell SV and Simplorer SV along with their example files, please visit the web site for this book:
ftp://ftp.wiley.com/public/sci_tech_med/magnetic_actuators/

This book is divided into four parts, each containing several chapters. Part 1, on *magnetics,* begins with an introductory chapter defining magnetic actuators and sensors and why they are important. The second chapter is a review of basic electromagnetics, needed because magnetic fields are the key to understanding magnetic actuators and sensors. Chapter 3 is on the reluctance method, a way to approximately calculate magnetic fields by hand. Chapter 4 covers the finite-element method, which calculates magnetic fields very accurately via the computer. Magnetic force is a required output of magnetic actuators and is discussed in Chapter 5, and other magnetic performance parameters are the subject of Chapter 6.

Part 2 is on *actuators.* Chapter 7 discusses DC (direct-current) actuators, while Chapter 8 deals with AC (alternating-current) actuators. The last chapter devoted strictly to magnetic actuators is Chapter 9, on their transient operation.

Part 3 of the book is on *sensors.* Chapter 10 describes in detail the Hall effect and magnetoresistance, and applies these principles to sensing position. Chapter 11 covers many other types of magnetic sensors. However, types of sensors involving quantum effects are not included, because quantum theory is beyond the scope of this book.

Part 4 of the book, on *systems,* covers many systems aspects common to both magnetic actuators and sensors. Chapter 12 presents coil design and temperature calculations. Electromagnetic compatibility issues common to sensors and actuators are discussed in Chapter 13. Electromechanical performance is analyzed in Chapter 14 using coupled finite elements, while Chapter 15 uses electromechanical systems software. Finally, Chapter 16 shows the advantages of electrohydraulic systems that incorporate magnetic actuators and/or sensors.

Many examples are presented throughout the book because my teaching experience has shown that they are vital to learning. The examples that are numbered are simple enough to be fully described, solved, and repeated by the reader. In addition, problems at the ends of the chapters enable the reader to progress beyond the solved examples.

I would like to thank the many engineers whom I have known for making this book possible. Starting with my father, Robert C. Brauer, P.E., it has been my great pleasure to work with you for many decades. I thank my wife, Susan McCord Brauer, for her encouragement and advice on writing. Thanks also go to the reviewers of this book for their many excellent suggestions. All of you have taught me many things. This book is my attempt to summarize some of what I've learned and to pass it on.

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